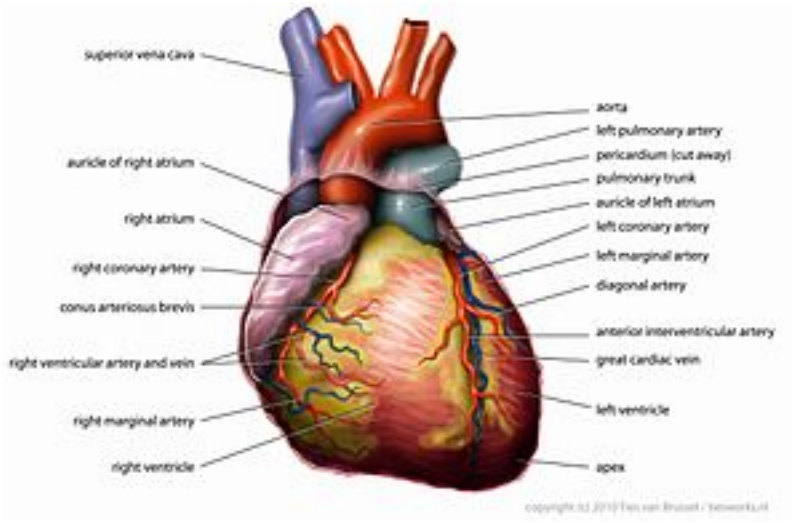
Overview of skeletal and cardiac muscle physiology and measurements

January 16, 2014

Heart



Skeletal Muscle

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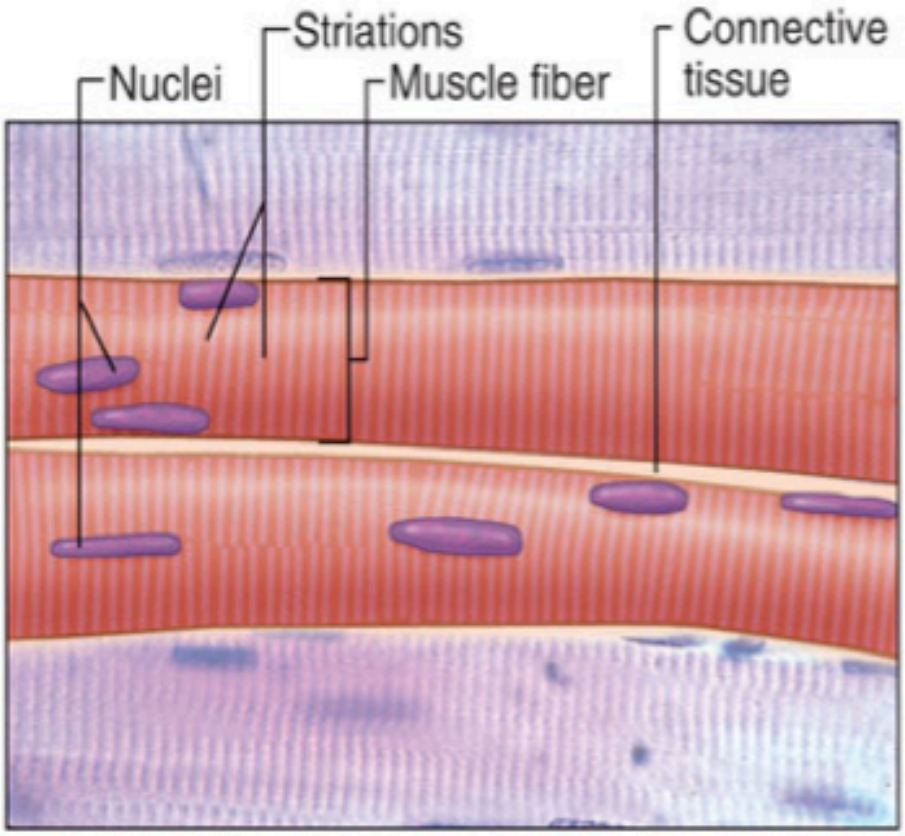
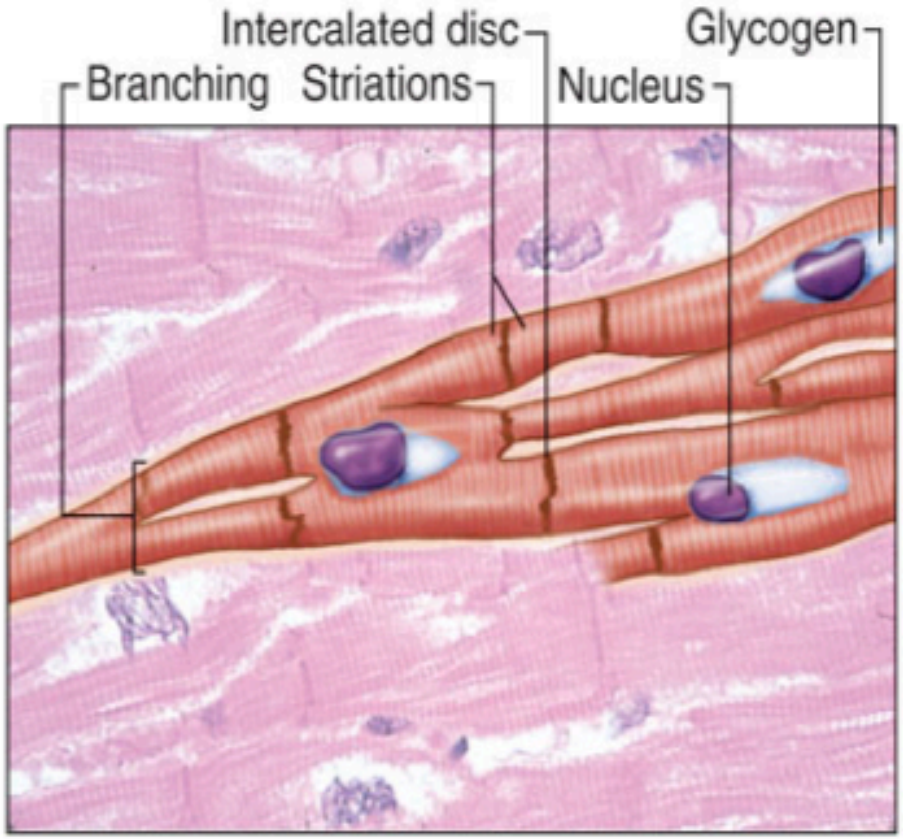
Muscle Physiology, basics

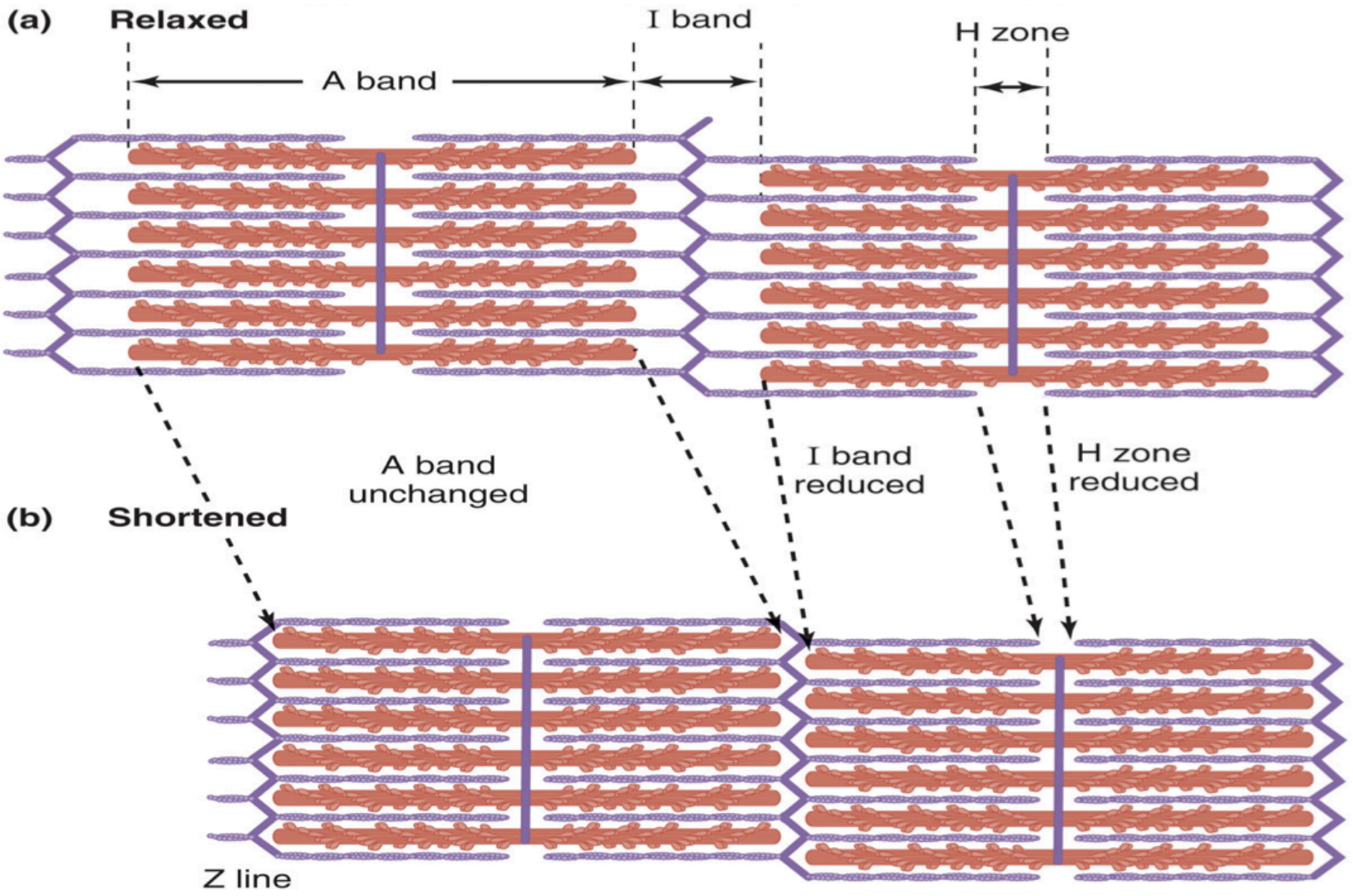


(a) Skeletal muscle



(b) Cardiac muscle

Muscle Physiology, basics



Muscle Physiology, basics

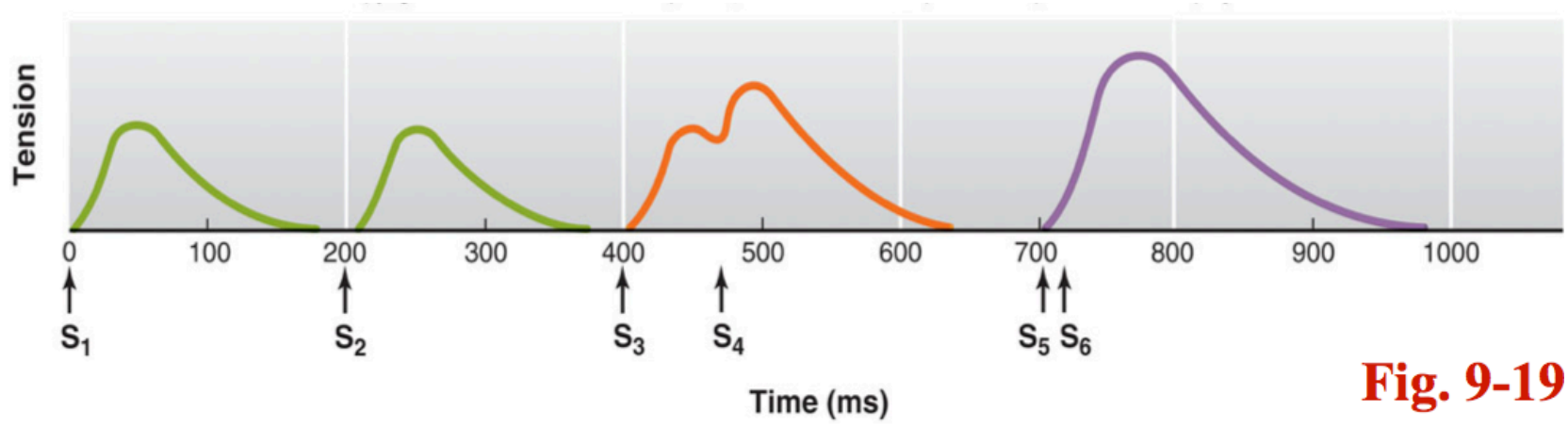
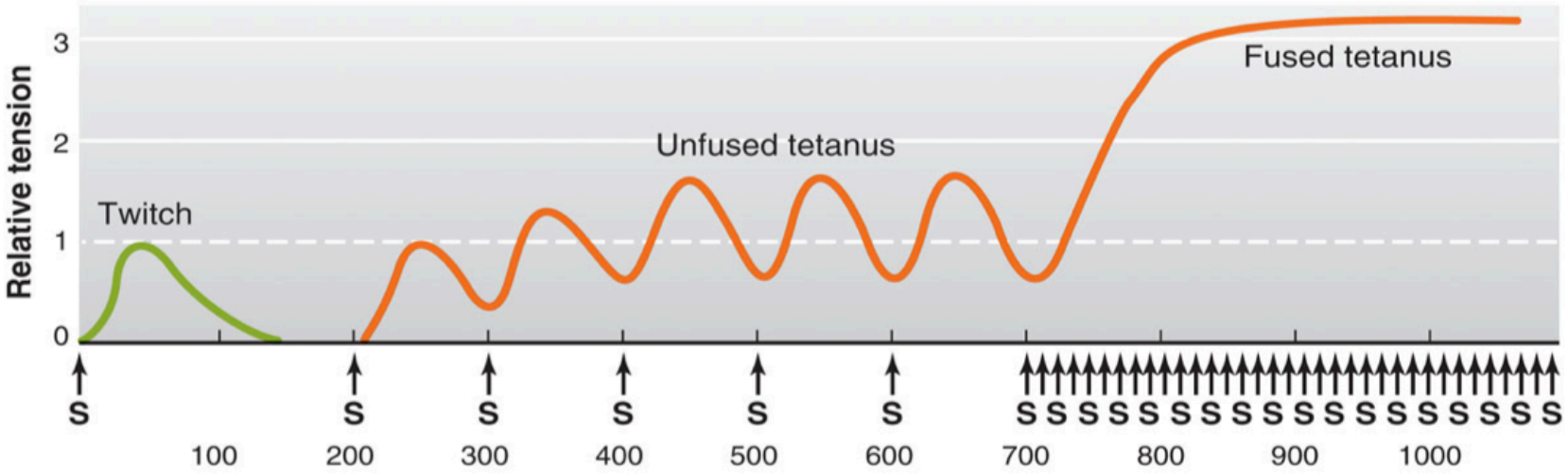
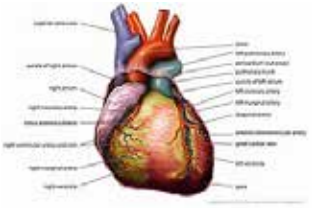


Fig. 9-19

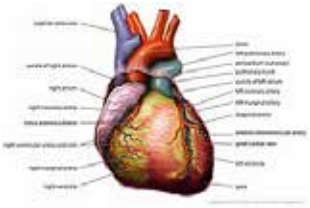


The heart: basics



- The heart is a muscle
- It pumps ~1 time per second at rest
- It pumps 5 liters of blood per minute
- Malfunction of the heart = #1 killer

How to measure cardiac muscle function



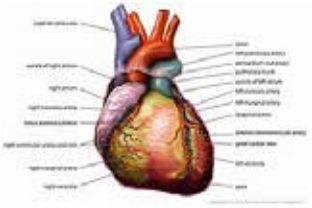
Level

- Society
- Subject
- Organ
- Sub-organ
- Cell
- Sub-cell
- Molecule

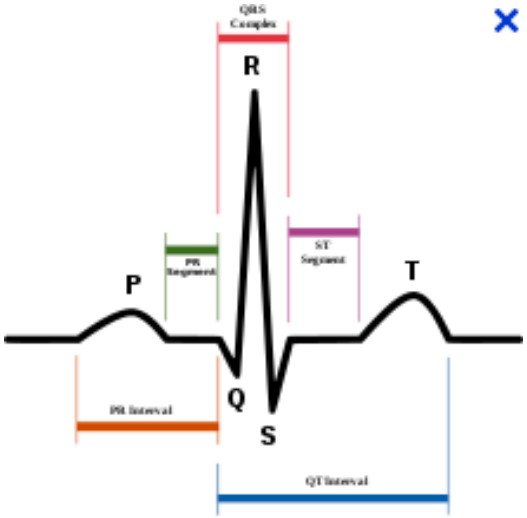
Function

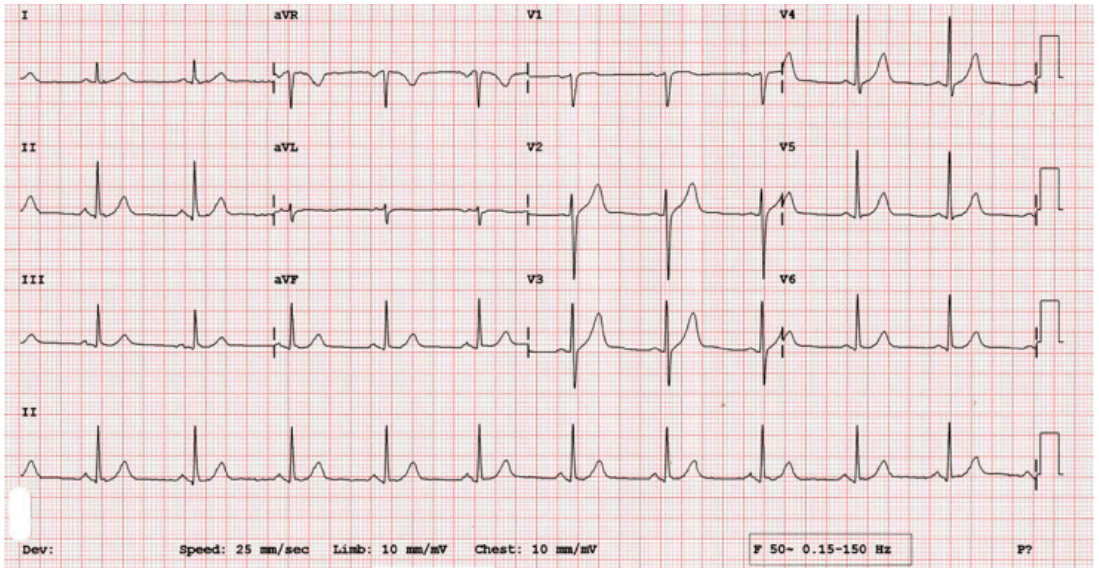
- Electrical
- Mechanical
- Secretion/Uptake
- Chemical
- Anatomical/Histological

How to measure cardiac muscle function



Whole subject: ElectroCardioGram

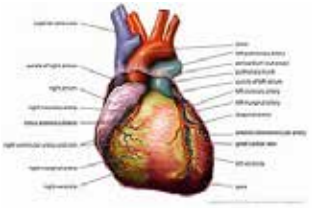




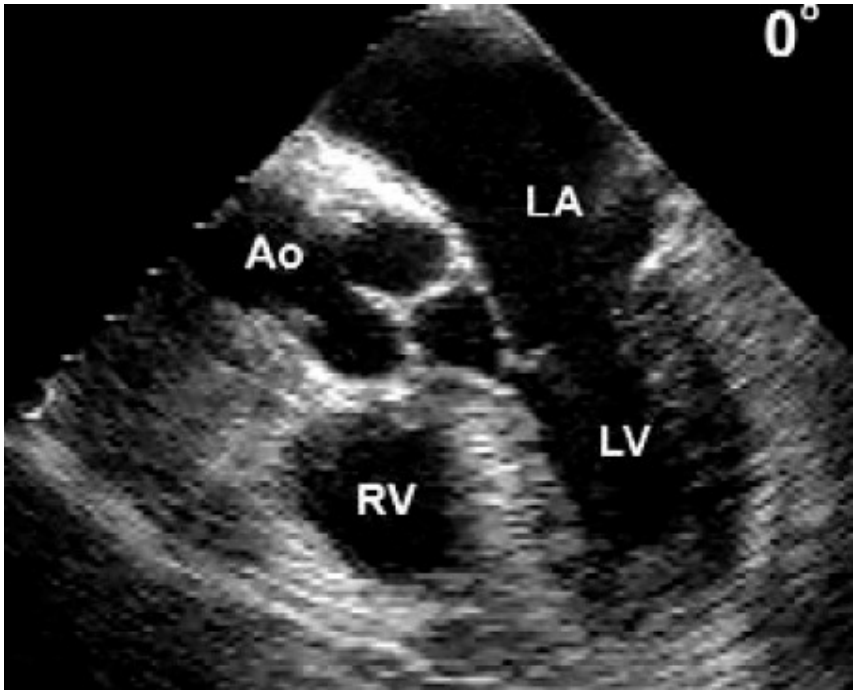
Mainly assesses electrical processes, can however indicate histological parameters

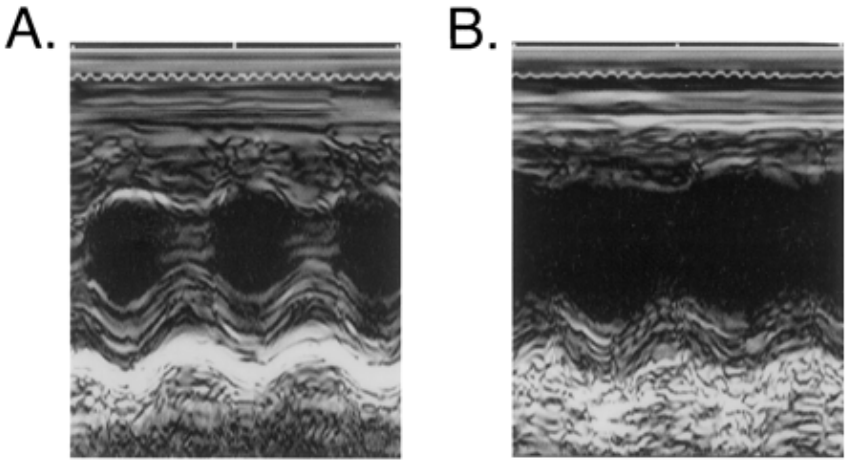
Most common parameters: RR-interval (HR), HRV, QT-duration

How to measure cardiac muscle function



Whole subject: Echocardiograhpy

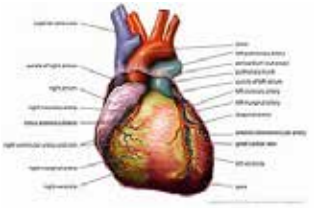




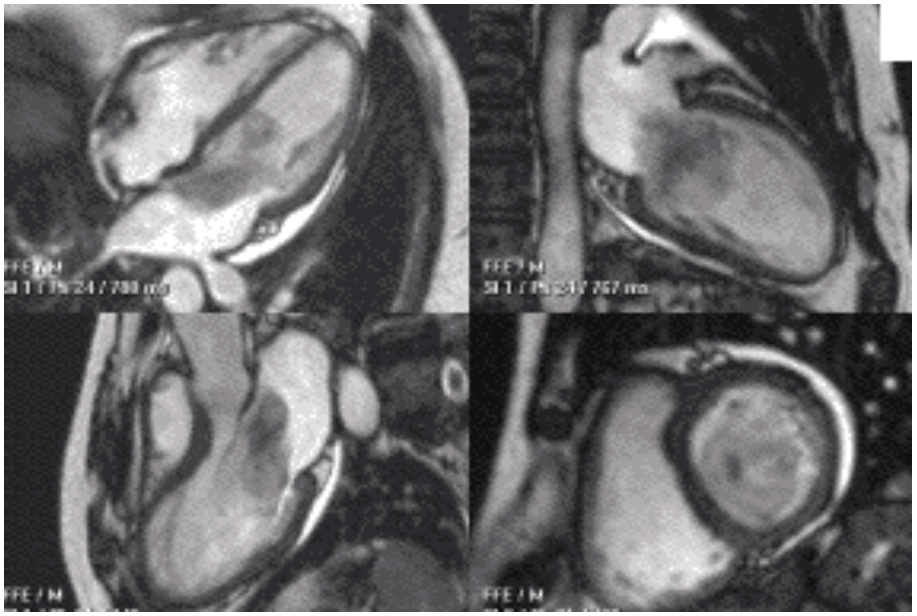
Most common parameters: Ejection Fraction, Fractional Shortening, EDV, ESV, SV

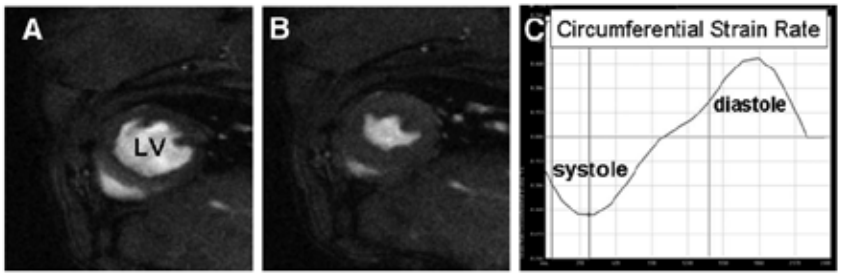
Mainly mechanical processes, different modes

How to measure cardiac muscle function



Whole subject: MagenticResonanceImaging

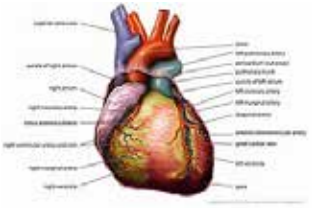




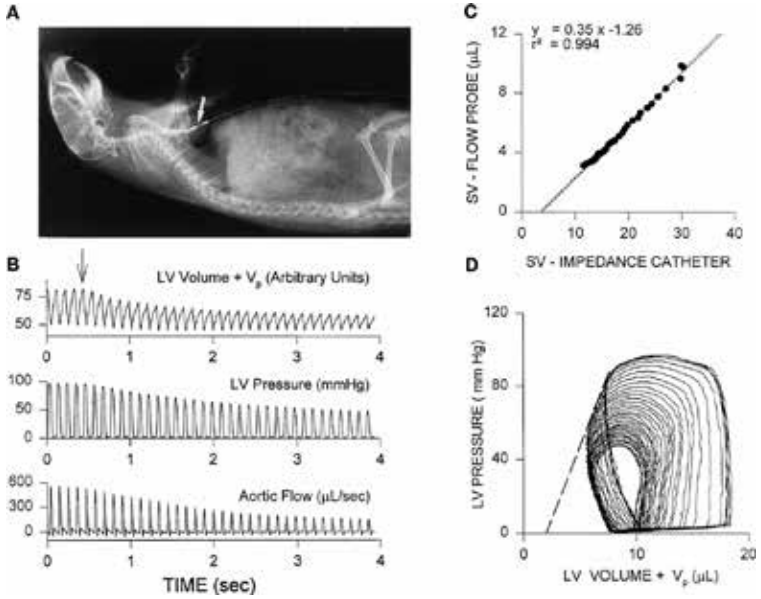
Most common parameters:
Ejection Fraction, Fractional Shortening, EDV, ESV, SV, Myocardial strain

Mainly mechanical processes, different modes

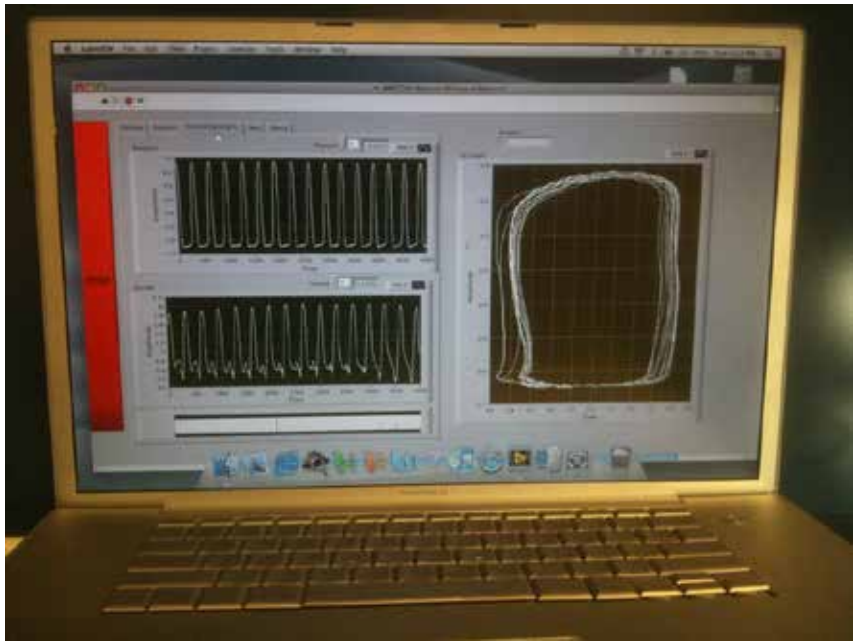
How to measure cardiac muscle function



Whole organ: Pressure Volume Assessment

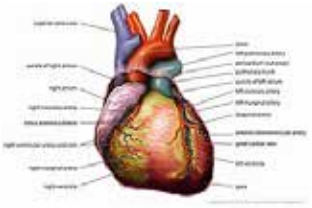


Most common parameters: Ejection Fraction, Fractional Shortening, EDV, ESV, SV, Myocardial strain, EDP, ESP

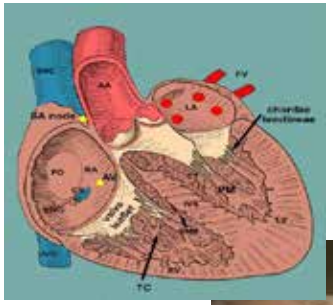


Mainly mechanical processes

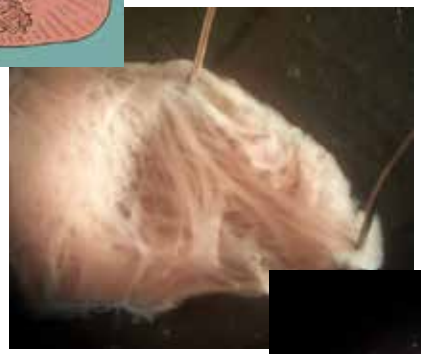
How to measure cardiac muscle function

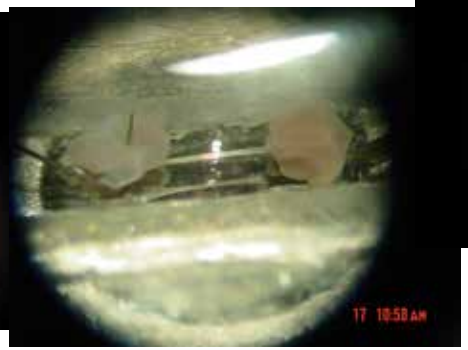


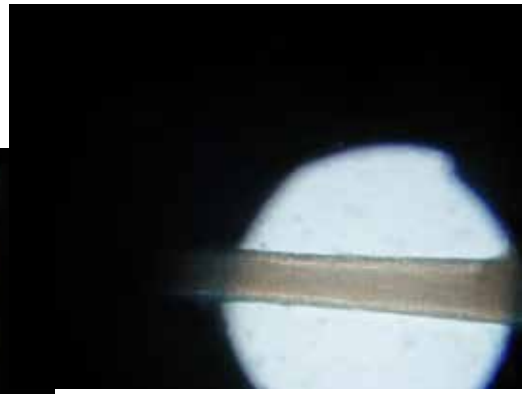
Sub-Organ: Isolated Trabeculae



Most common parameters:
Specific Force
Intracellular Calcium

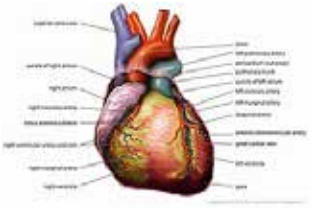




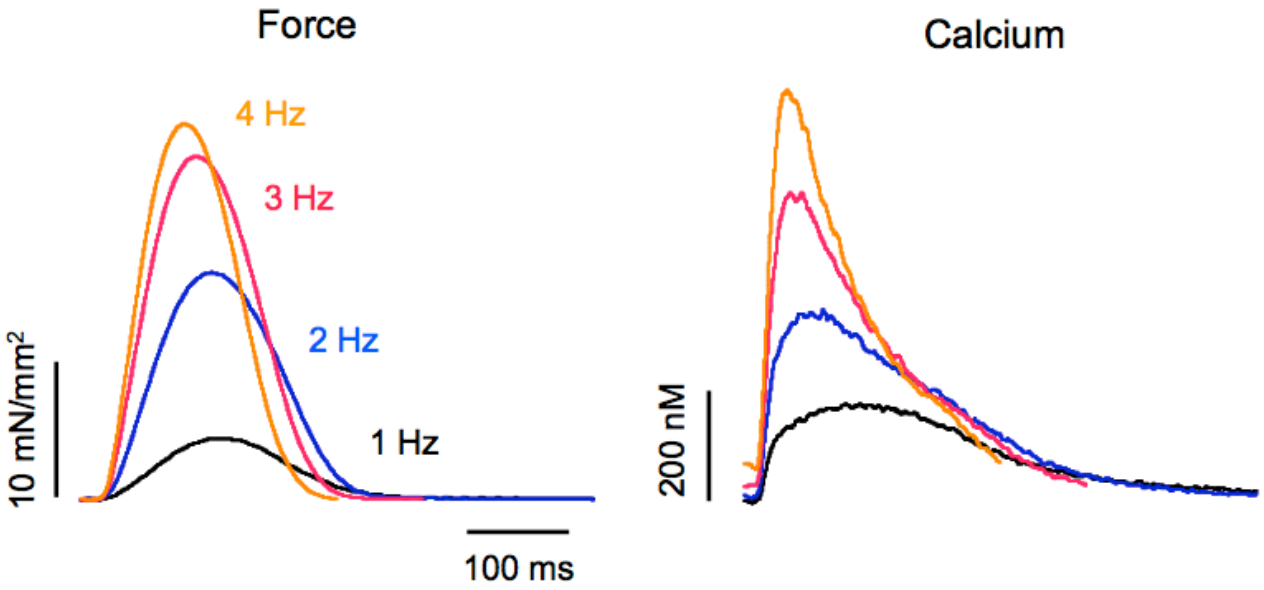


- *Loaded Contractions*
- *Physiological Frequency*
- *Body temperature*

How to measure cardiac muscle function

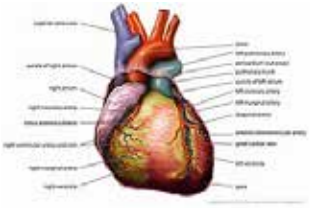


Sub-Organ: Isolated Trabeculae

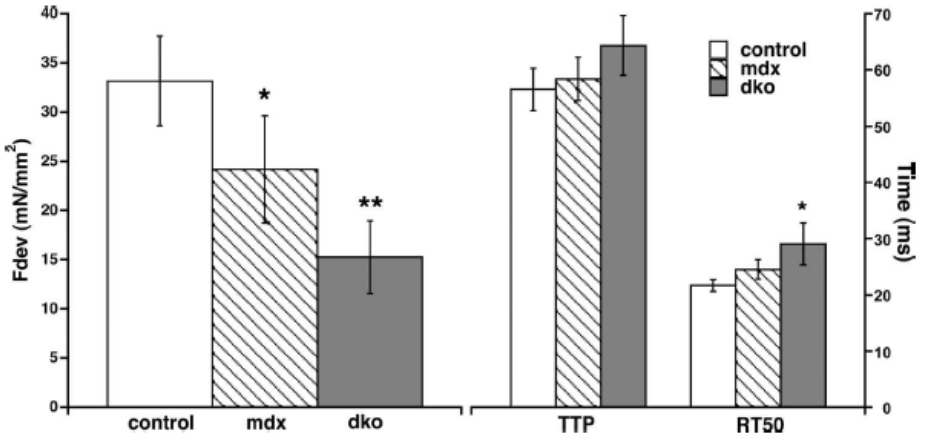


- Muscle force typically declines before whole heart function declines
- Whole heart function compensated on many levels

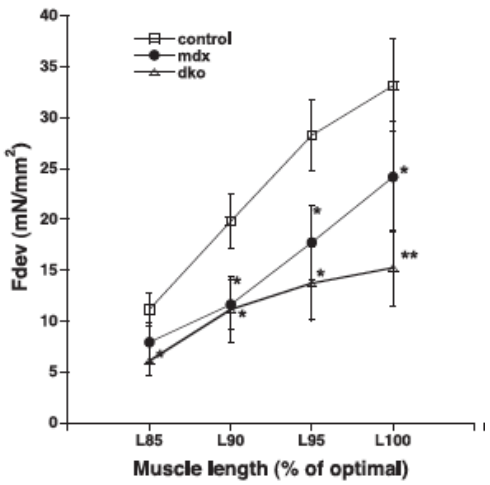
How to measure cardiac muscle function

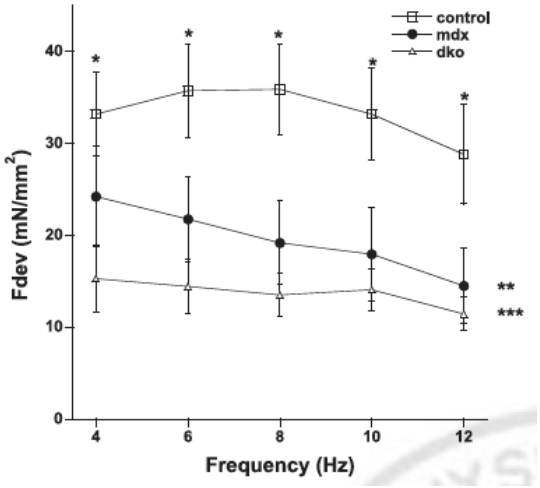


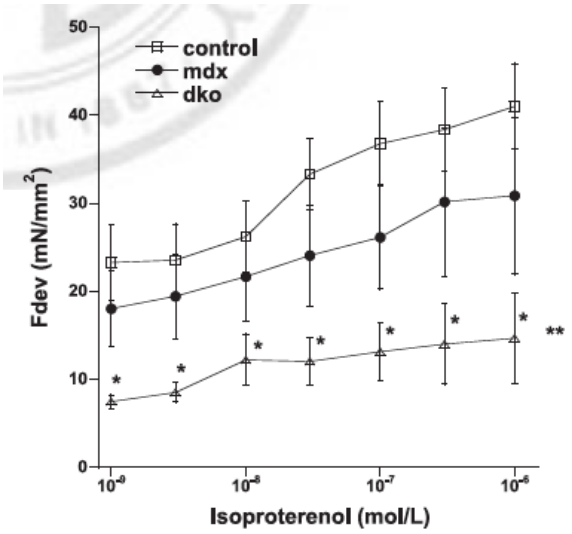
Sub-Organ: Isolated Trabeculae



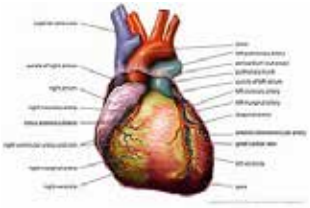
- Frank-Starling (volume/length)
- Bowditch (heart rate)
- FFR (β-stimulation)



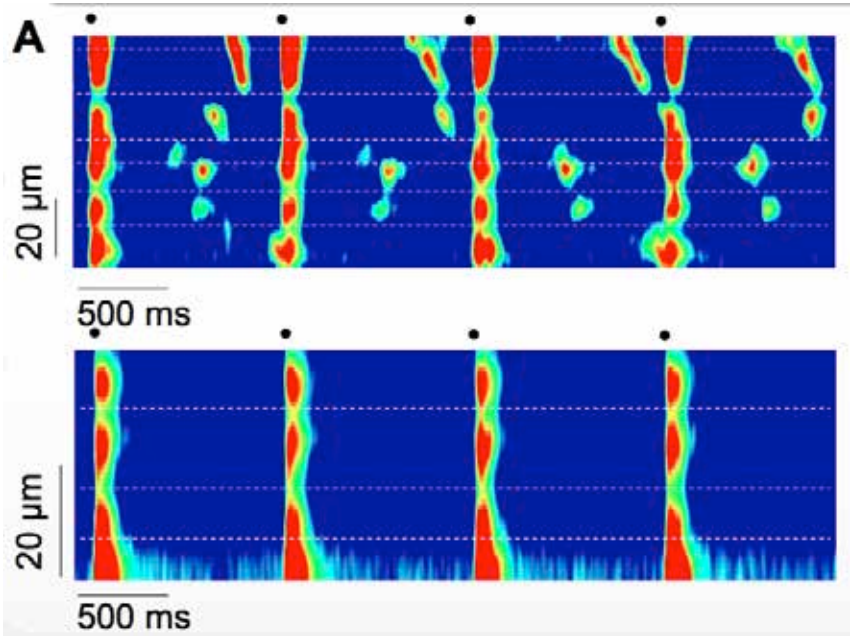


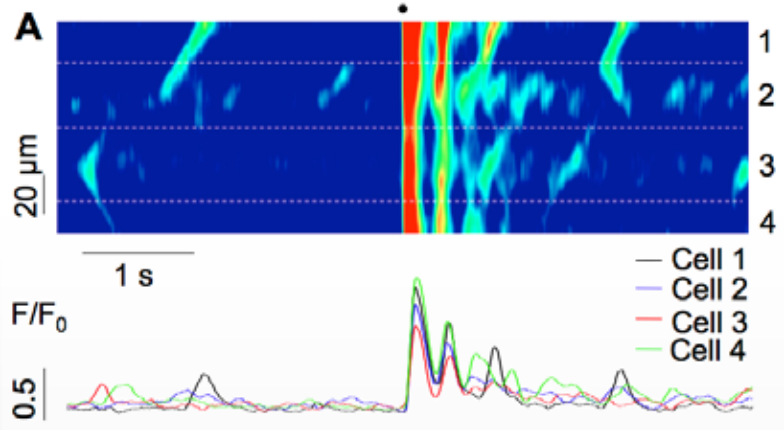


How to measure cardiac muscle function



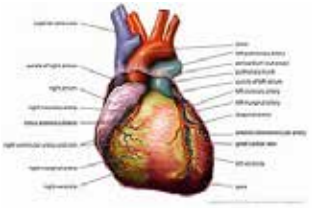
Sub-Organ: Isolated Trabeculae





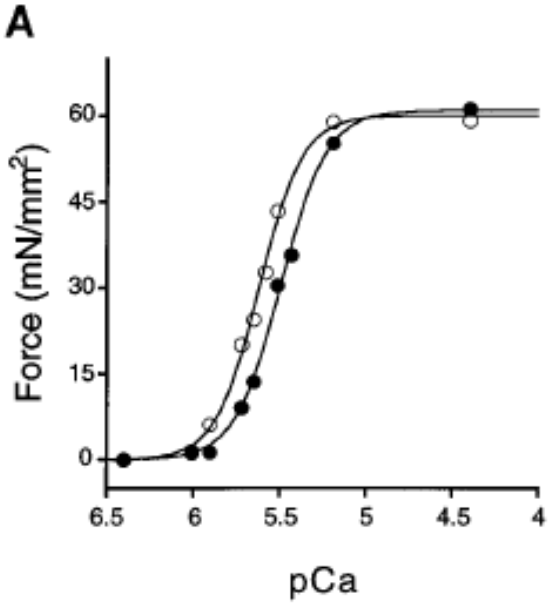
- Imaging of Calcium in multiple cells
- Study contractile and electrical effects

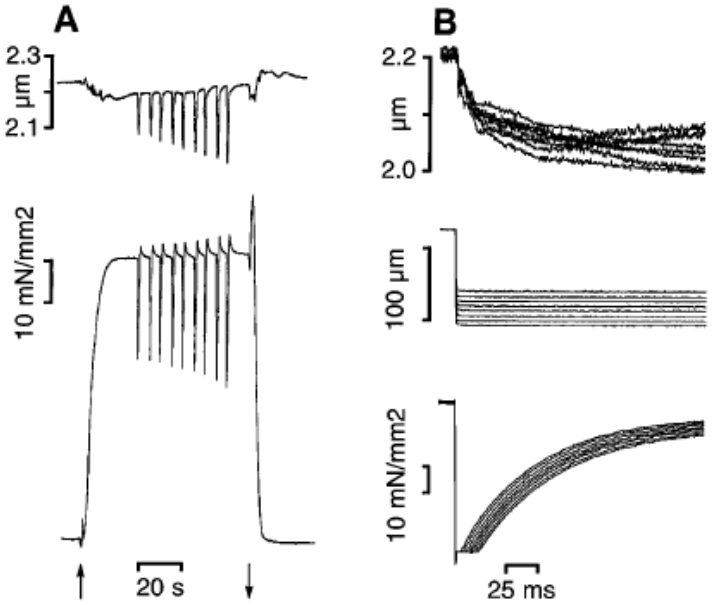
How to measure cardiac muscle function



Sub-Organ: Isolated Trabeculae

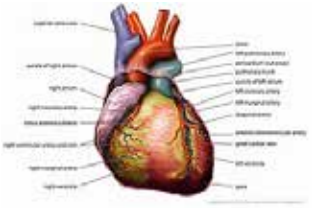
Permeabilized muscles



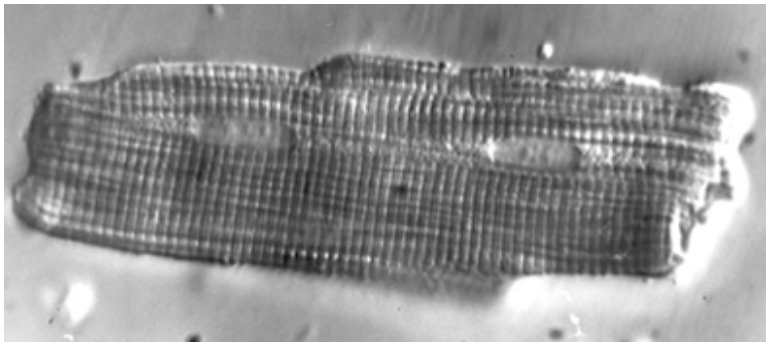


- Myofilament function, calcium is dictated by the investigator
- Measure speed of contraction, sensitivity for calcium

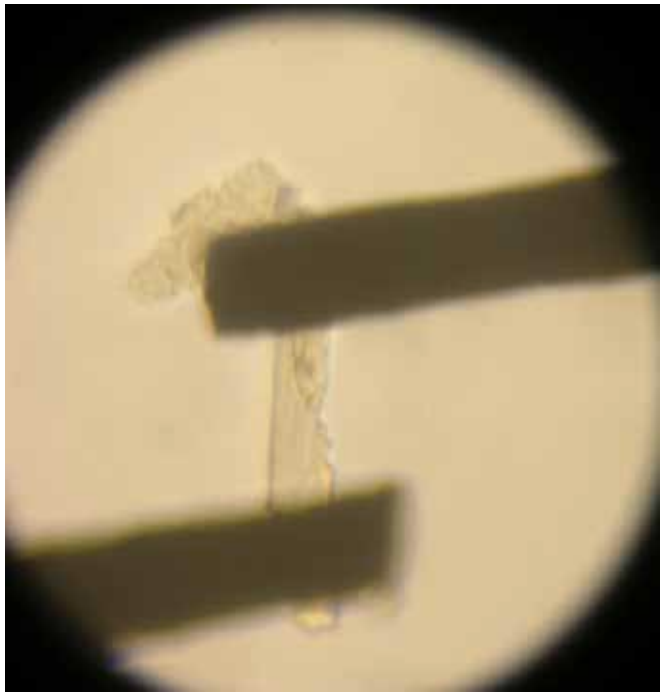
How to measure cardiac muscle function



Cell: Isolated myocyte

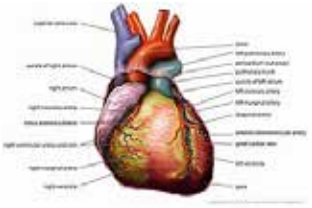


- Measure unloaded cell shortening
- Measure calcium transients

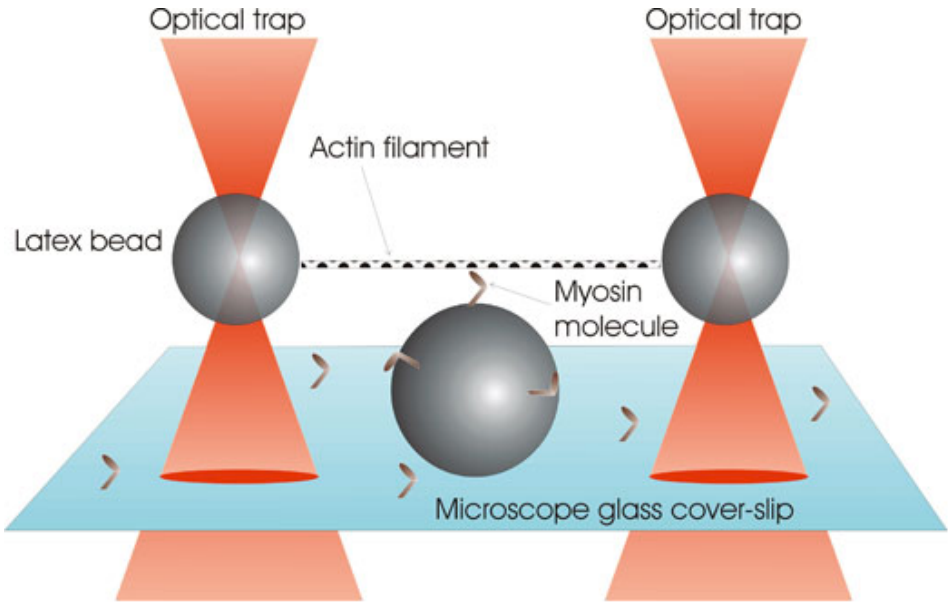


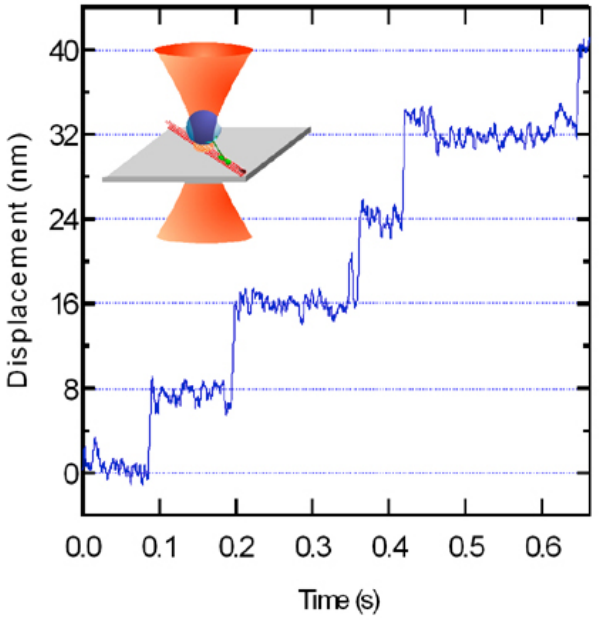
- Measure loaded cells
- Incompletely developed

How to measure cardiac muscle function



Molecule: Single protein





- Measure single molecule force and kinetics

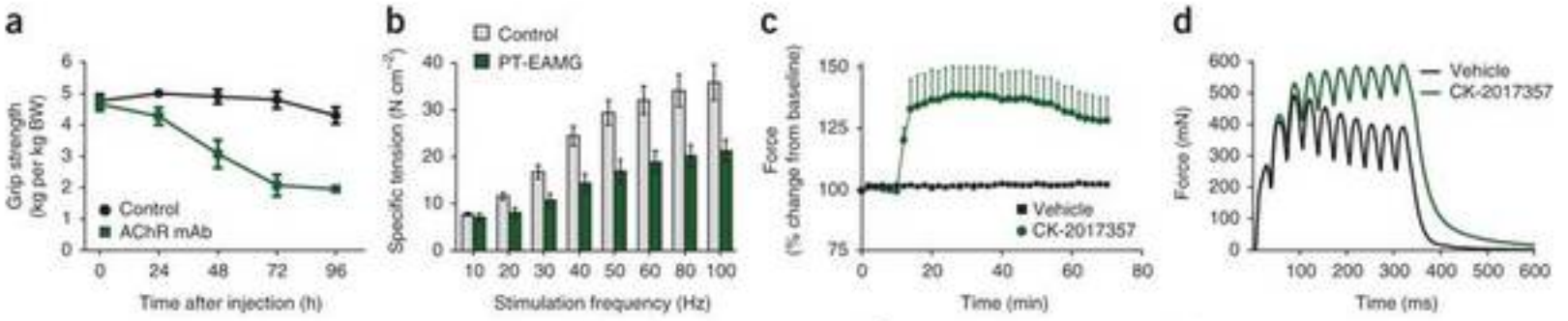
How to measure skeletal muscle function

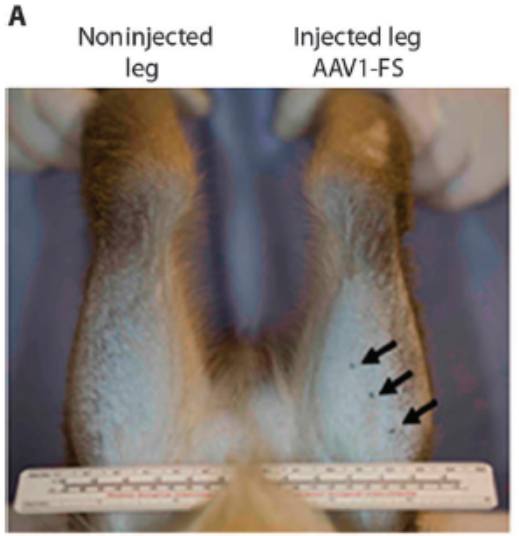
Whole subject: Muscle strength test

- Measures overall force, often measures quantity
- Under cognitive control, motivation

How to measure skeletal muscle function

Organ: In Situ Blood-perfused Whole Muscle





- Measures overall force, electrical
- override of neuronal control

How to measure skeletal muscle function

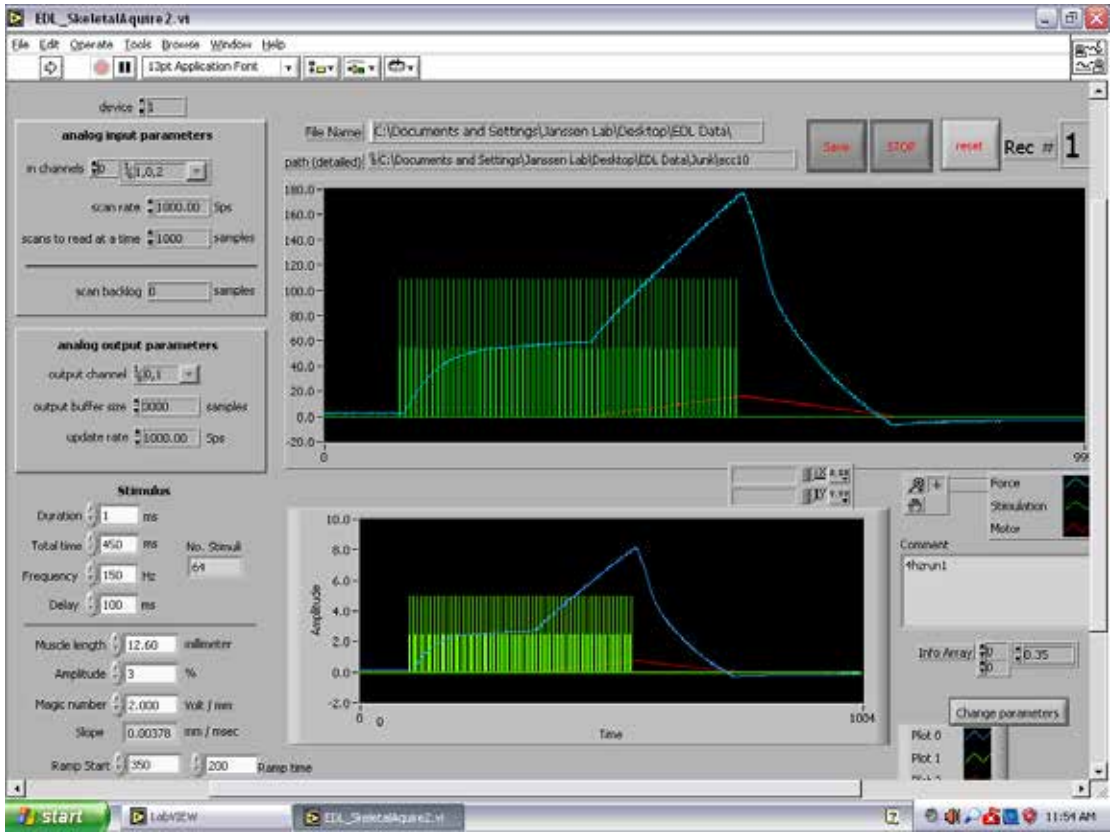
Organ: In vitro muscle contractions

EDL

Diaphragm

How to measure skeletal muscle function

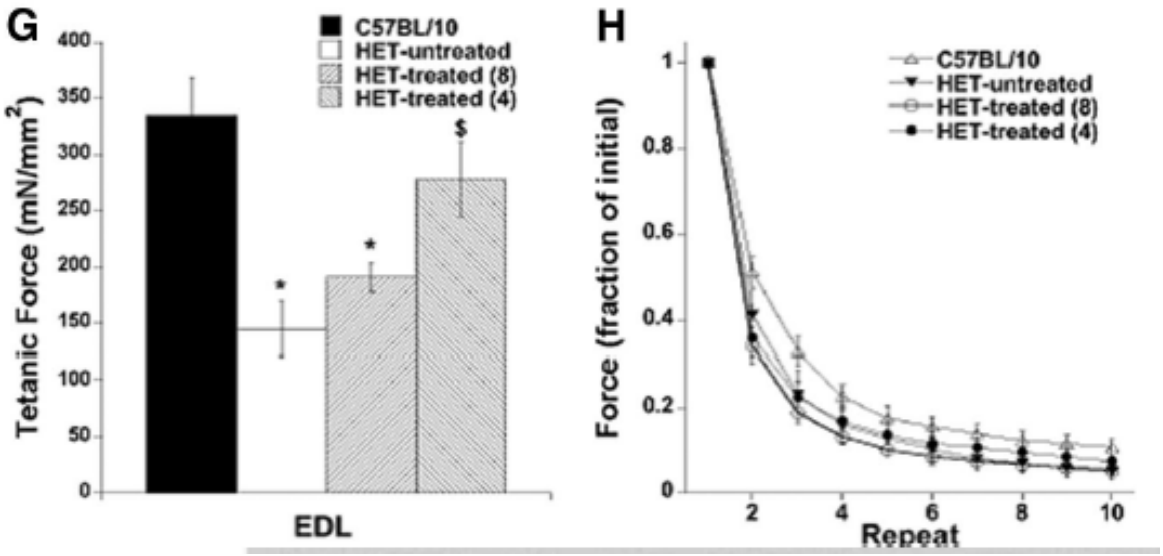
Organ: In vitro muscle contractions in EDL



- Measures total force (N)
- Measures specific force (mN/mm^2)
- Twitch contraction or tetanus
- Can measure mechanical perturbation

How to measure skeletal muscle function

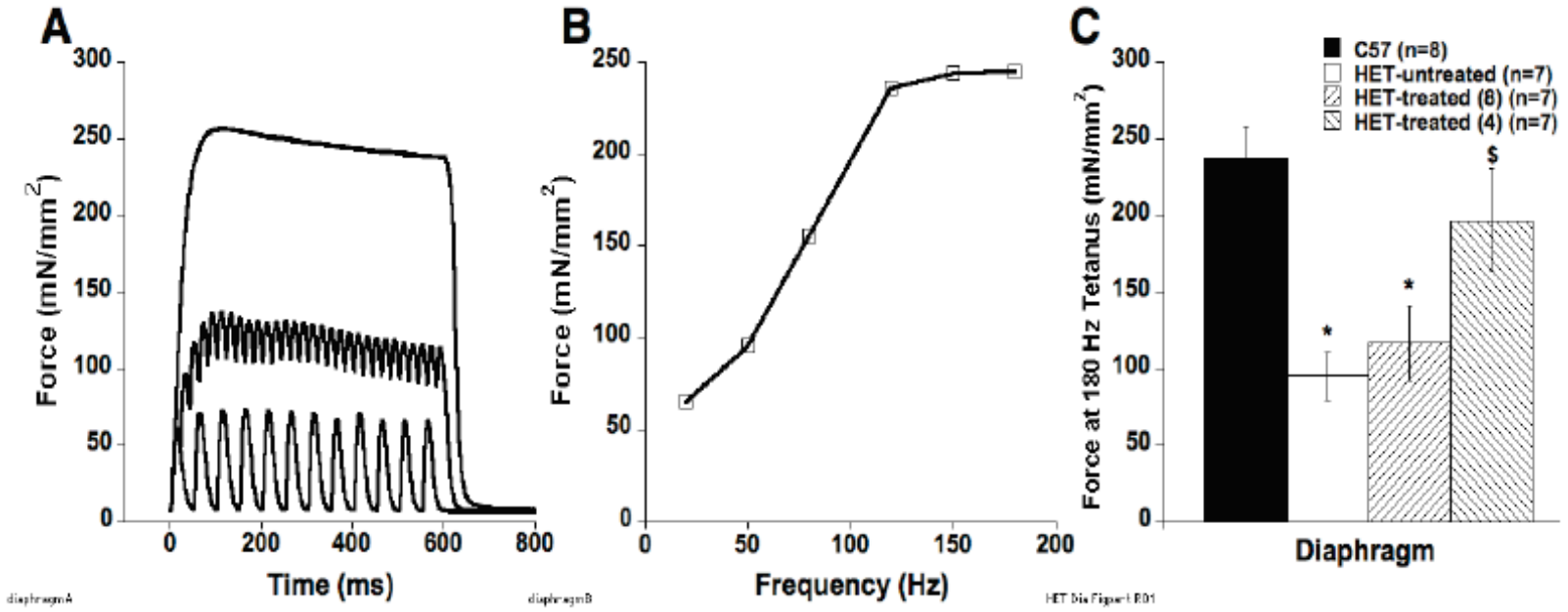
Organ: Eccentric Contractions in EDL



- Measured resistance to mechanical stress
- Typ. 5-10 contractions

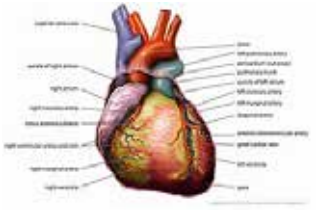
How to measure skeletal muscle function

Sub-Organ: Diaphragm contractions



- Measures Twitch and Tetanic Specific Force, frequency-dependency
- Can measure fatigue and decay

What to measure?



- Various factors figure into design:

- What is the question?
- Cost
- Resolution
- Throughput